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Hydrology and Earth System Sciences Discussions

Interactive comment on "Controls on the temporal and spatial variability of soil moisture in a mountainous landscape: the signatures of snow and complex terrain." *by* C. J. Williams et al.

Anonymous Referee #2

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This is an interesting paper on the spatial and temporal patterns in soil moisture. The authors studied the spatial variability and temporal stability of soil moisture in a semi-arid snow-dominated steep watershed and specifically the controls of topography and soil depth (static variables) and snow depth and snow melt (dynamic variables) on it. This research is novel because it looks at the important effects of spatial variation in inputs (snow) on the soil moisture distribution in a small watershed. Other studies that have looked at the effects of spatially variable input (rain) on soil moisture were always done in larger watersheds. In addition, most other studies on the spatial variation in soil moisture were done in rainfall dominated watersheds.

The paper is well written and the figures are clear (although I would like to see the data of more measurements plotted in Figure 5). I particularly like it that all the data is given in the tables so that it can be used by other people for model testing or site comparisons.

Unfortunately, the discussion section is not very clear (see major comments below) because there are a couple of unexplained contradictions. It is shown that soil moisture at depth does not respond until late in the winter. Yet lateral flow (at depth) is invoked to explain the soil moisture pattern. Many other researchers have used lateral flow to explain the soil moisture distribution. However, in this case (as in many others) it is not clear why lateral flow at depth would result in a distinct pattern in shallow soil moisture (especially when the soil profile has not been fully wet up yet).

Major comments:

1) P1942:L9: You attribute these patterns to snow accumulation and snow melt. Yet, there is only a weak correlation to the snow variables. Thus the visual comparison of the maps is more convincing than the correlation analyses. You should state this explicitly in the text and discuss this difference as well. Is this because of the problems related to the measurement scales (i.e. that you are comparing point measurements rather than patterns)? The correlation with distance to the divide is stronger than the correlation with snow. Doesn*t this suggest that it is mainly flow controlled rather than input controlled? This is currently not discussed in the discussion section.

2) P1942L27: During the early December period soil moisture at depth (thus above the bedrock layer) has not increased yet (see your Figure 3 and discussion related to Figure 3). Thus the hypothesis about bedrock flow or subsurface stormflow over the bedrock seems to make little sense for this period. There thus is a contradiction in the story that needs to be discussed better. Do you have evidence for lateral flow while the soil is still wetting up?

3) Sections 5.1 and 5.2. Subsurface flow is invoked as a partial reason for the observed

HESSD

5, S1063–S1068, 2008

Interactive Comment

soil moisture patterns. I think that this section needs to be written more as a possible hypothesis. I agree in part that this is plausible and likely but you do not provide any data or measurements in this paper that show that subsurface flow actually took place during these periods. If there is (better) evidence regarding the importance of subsurface flow, these sources need to be referenced better. While lateral flow seems very plausible, there is no description or explanation for why lateral flow at depth would lead to increased shallow soil moisture. Or do you expect the lateral flow to take place in the top soil layers? The description in section 5.1 seems to suggest that you assume that lateral flow takes place at depth. Please clarify.

4) P1943L13: Because the soils there are shallower the volumetric moisture content will decrease faster, even if the evapotranspiration loss and initial moisture content are the same.

5) P1941L16-18: It is interesting that individual points occasionally experience large changes in rank. But this is not discussed in the discussion section. It would greatly add to the paper, if this was discussed in more detail. Why is this the case? Is this because the measurements were made manually and thus inserted in a slightly different plot each time so that one time it can be close to a rock but next time it is not? Or because each location has a slightly different bulk density? Or is this mainly because the spatial pattern/spatial variability in soil moisture changes so quickly?

6) P1946L15: Point 3 is only valid from the wet through the dry down period. You show on P1939L21 that there are only 2 points consistently wet and that there is only 1 point consistently dry. Thus statements 1-3 on P1946 are only valid from the wet-dry down period.

7) P1947L27: I appreciate the link to climate change and think that this is an important one. It would greatly add to the paper if you could speculate (based on your results) how the soil moisture patterns would change. Would it look more like the wetting up stage?

HESSD

5, S1063–S1068, 2008

Interactive Comment

8) Figure 5: It would be much better to show more maps (e.g. 2 dates for each state) so that the patterns are clearer and it is easier for the reader to follow the text. Now the reader does not get a sense of the variability within each state.

Minor comments:

1.) P1931L19: list the catchment properties

2.) P1933L15: Were these surface soil samples? Samples from the top 30 cm? Give the depth of the samples? What was the size of the soil samples?

3.) P1935L19: How many plots?

4.) P1934L29: How did you deal with the snowpack? Did you remove the snow before inserting the soil moisture sensor? Or did you extend the rods of the soil moisture sensor so that they could be inserted through the snowpack? Or are all the measurements that occurred when there was a snowpack excluded from the analyses? This is not clear in the current methods section.

5.) P1934L5: Was this an average snow year? Or a dry year?

6.) P1935L16: Insert *the relative difference (dij)* before equation 2. Now it looks like equation 2 is the mean relative difference not the relative difference.

7.) P1937 / Section 4.1 it seems that this section could equally well moved to the site description.

8.) P1940L16-18: Explicitly mention what the numbers in the parentheses represent.

9.) P1940L27-28 and P1941L1-2: Insert at the end of the sentence *except during the wet-up period* as you write on L3-4 of P1940 that this is not the case during autumn rains.

10.) P1941: I really like the idea and calculation of the rank change index (RCI). It would be good to add a figure showing the spatial distribution of RCI. This will make

HESSD

5, S1063–S1068, 2008

the spatial variability/spatial pattern in RCI much clearer to the readers.

11.) P1942L28: It is important to stress here that the soils are a lot shallower there.

12.) P1947L11: State explicitly that the spatial pattern of soil moisture (and relative difference) does change during this period.

13.) P1947L14 and L17-18: Again, state that this is only for the wet-dry period as on P1939 you state that it is not the case for the wetting up period during fall rainfall events.

14.) Figure 2: What method was used for the interpolation? It would be better to show the actual measurement locations as well. Finally, it would be helpful if the figure would be a bit bigger.

15.) Figure 3: It would be helpful to plot the snow depth as well.

16.) Figure 6: It would be easier to see the points if the figure was split into 2 parts (a with the time stability and b with the other correlations). Also, the figures would be clearer if the lines showing the representative states would span the whole plot as in figure 3 and not just the data range.

Minor editorial comments:

*) P1982L18-21: this sentence does not flow very well. Rewrite.

*) P1982L21:Insert *that* between *demonstrate* and *snow*

*) P1982L22: Insert *we* before *infer*

*) P1929L4: Replace *while also is a* by *while it is also a*

*) P1931L9: Replace *declines on 1 April* by *declines of 1 April*?

*) P1931:L19: It is clearer if you replace *scales* by *changes with*

*) P1938L17: Replace *to a depth* by *at a depth*

HESSD

5, S1063–S1068, 2008

Interactive Comment

*) P1939L20: Insert *(MRD)* after *Mean relative difference*

*) P1939L21: Replace *MRD* by *dij_bar*

*) P1940L7: Replace *soil moisture content* by *mean relative difference* (soil moisture content is always a positive number)

*) P1942L5: Insert *During* before *A wet*

*) P1947L19: Insert *that* between *suggest* and *snow*

*) P1947L21: Replace *mountain* by *mountains*

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 1927, 2008.